CLEAR SKIES AHEAD!

Clearing Up Confusion About Clouds

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One salient aspect of meteorology is the notion that current atmospheric conditions can provide insight into future weather events. A prominent feature of atmospheric conditions that can be easily observed by students of all ages is clouds. There are a wide variety of cloud types that can be observed, and certain cloud types tend to correspond to other observable weather events (Bryson 2004). However, we have observed that many students and teachers find it challenging to distinguish among common cloud characteristics, such as physical description, elevation, and precipitation, which can be useful in helping to predict future weather events.

Without the need for expensive observation equipment, students can easily walk outside their classroom, look up, and learn from the clouds they see in the sky. Through using a semi-dichotomous key to differentiate among subtle variations in physical descriptions, elevation, and precipitation, and then analyzing descriptive observations of the sequential change in cloud types over a six-hour time span, students can forecast future weather events. These forecasts become more accurate when students

FIGURE 1

The three common cloud-type descriptions (a) wispy (cirrus), (b) flat (stratus), and (c) puffy (cumulus)

a.

b.

c.
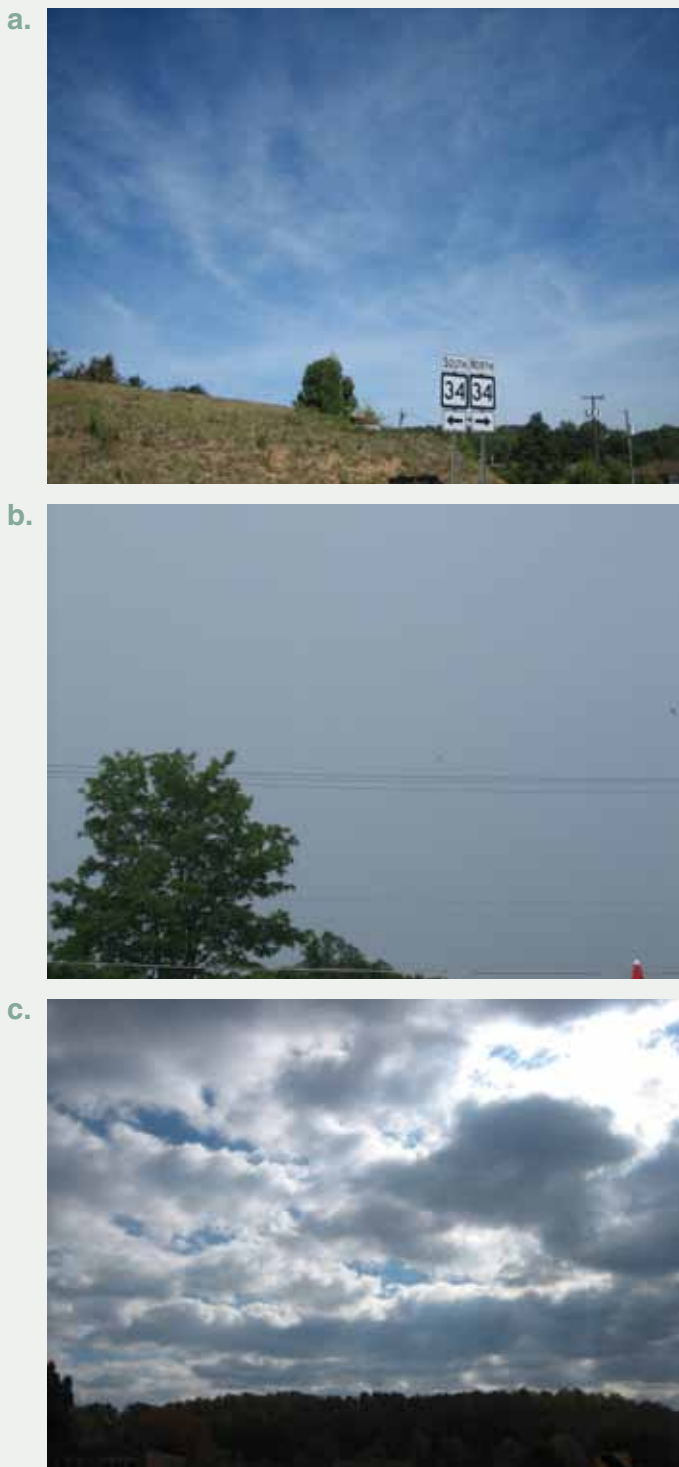
also incorporate weather variables such as atmospheric pressure, temperature, wind direction, and precipitation.

In this article, we present an inquiry-based approach to facilitate student understanding of the differences among common cloud descriptive characteristics through the use of a semi-dichotomous key developed by a former West Virginia state climatologist. We also demonstrate how students can analyze common class data sets that describe the outcomes from the semi-dichotomous key throughout a school day to predict future weather events. Whereas other approaches to teaching about common cloud descriptive characteristics have relied on the identification of various cloud types through the use of pictures, this approach is novel in that we present a semi-dichotomous key with tangible descriptions to help students differentiate among subtle variations in physical characteristics. Furthermore, student analysis of common class data sets that describe the sequential change in cloud types over relatively short periods of time are then used to develop hypotheses about the changes in atmospheric conditions that may follow such observations.

Common cloud descriptive characteristics

Clouds can be easily identified by students with an understanding of the interaction of three common cloud descriptive characteristics: physical description (what it looks like), elevation (how high it is), and the presence of precipitation (whether it's raining or snowing). These three common cloud descriptive characteristics are interrelated and provide the basis for the naming convention of clouds. In order for students to observe the sequential change in cloud types to predict future weather events, they need to be able to distinguish among common cloud descriptive characteristics and analyze the transitions between cloud types over a six-hour time span. Moreover, developing student understanding of the interaction among the three common cloud descriptive characteristics will help to provide them with all the essential pieces required to identify all the major cloud types.

Common cloud naming convention

The Latin-based naming convention of clouds is based on Luke Howard's description of common cloud types (Howard 1833). Cirrus clouds look wispy, like a curl of hair or a horse's tail; stratus clouds are spread out, flat, or layered; and cumulus are heaped, puffy, or bumpy (see Figure 1). Clouds can also have different base elevations (see Figure 2). High clouds, with an elevation above 5,000 meters, utilize the cirro- or cirrus-naming convention (i.e., cirrus, cirrostratus, cirrocumulus). Middle clouds, with an elevation between 2,000 and 5,000 meters, utilize the alto-naming convention (i.e., altostratus, altocumulus). Low base clouds, with an elevation below 2,000 meters, utilize the stratus, strato-, or cumulus naming convention (i.e., stratus, stratocumulus, cumulus). Moreover, clouds can further be distinguished by the intensity of precipitation that is occurring (see Figure 3) while using either the nimbo- or nimbus-naming convention (i.e., nimbostratus, cumulonimbus). Cloud names are based on both how they look and the presence of precipitation, factors that are affected by elevation. Low clouds are composed primarily of water droplets, which give the cloud a sharply defined edge. These clouds also provide most of the precipitation that makes it to the Earth's surface. High clouds are composed of ice particles, which cause the edge of the clouds to appear fuzzy.

The instructional approach

We believe the use of a semi-dichotomous key is an effective approach that readily helps students to make descriptive observations of clouds on their own. All of the characteristics above have been summarized in the semi-dichotomous key shown in Figure 4. Each of the questions on the semi-dichotomous key describes a series of descriptive choices that students make as they progress through the decision-making process to decide on the observed cloud type. Our lesson plan facilitating student understanding of the differences among common cloud descriptive characteristics through the use of a semi-dichotomous key is illustrated in this article. This approach also incorporates the Know-Learn-Evidence-Wonder (KLEW) chart (Hershberg-

FIGURE 2 Clouds occur at different heights (a) high (cirro- or cirrus), (b) medium (alto-), and (c) low (stratus, strato-, or cumulus)
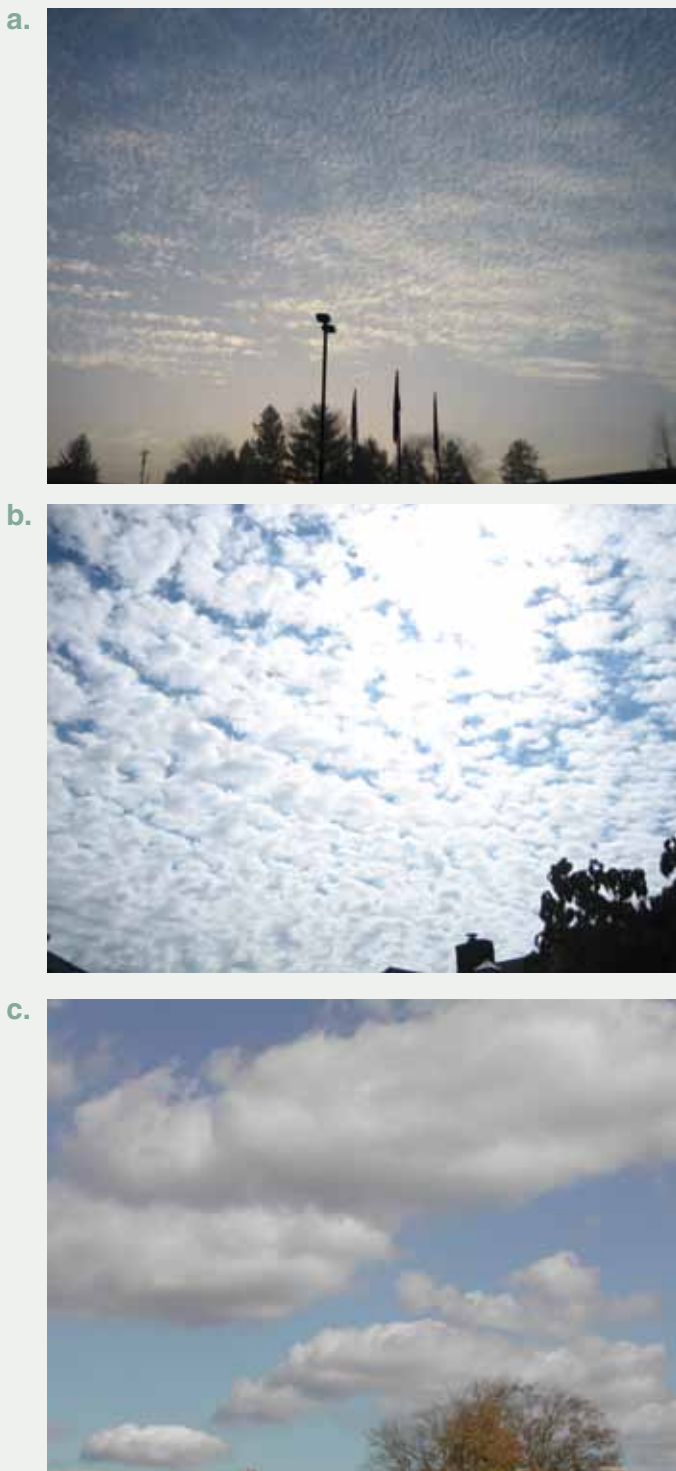
a.

b.

c.

FIGURE 3

Clouds exhibit two primary precipitation characteristics: (a, b) heavy downpour, often with thunder/lightning (cumulonimbus) or (c) a light steady rain (nimbostratus)

a.

b.

c.

er, Zembal-Saul, and Starr 2006) within the 5E learning cycle model (Bybee 1997) to document and provide evidence of student learning.

Here we demonstrate how our approach can help to facilitate students' understanding of clouds and allow them to predict future weather events. This topic fits well into an Earth science curriculum and *A Framework for K–12 Science Education*, which focuses on the fact that "scientists record the patterns of weather across different times and areas so that they can make predictions about what kind of weather might happen next" (NRC 2012, p 188). This topic further incorporates crosscutting concepts, such as patterns. As the Framework states, "Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them" (NRC 2012, p 84). Prior to this lesson, students learned about the water cycle and the common atmospheric variables, which include atmospheric pressure, temperature, wind direction, and precipitation. Students utilized meteorological instrumentation such as anemometers, weather vanes, rain gauges, and barometers to measure these common atmospheric conditions. This lesson, which was implemented in an Earth science class that was learning about clouds, takes four days to complete, 180 minutes total, assuming that most student groups would complete the Engage and Explore sections on day 1, the Explain and Elaborate sections on days 2 and 3, and the Evaluate section on Day 4.

Engage (day 1, 15 minutes)

Students are provided with a half sheet of paper and asked to sketch a cloud. The teacher draws or projects a sky map (see w*ww.wvgs.wvnet.edu/www/geoeduc/miscellaneous/Sketch-a-Cloud%20DH.jpg* for an example) on the screen in the front of the classroom with sky height indicators that represent high altitudes (skyscraper, mountain, high-flying plane), middle altitudes, and low altitudes (blimp, helicopter, small plane, tree). The teacher then instructs individual students to predict on the sky map where they believe their cloud would be found and to walk up to the front of the classroom and tape their cloud to the sky map.

Next the teacher asks students working in small groups to examine the sky map and discuss the following questions: (1) How high is your cloud on the sky map? (2) How are the clouds on the sky map similar or different? The teacher further elicits students' prior knowledge via a whole-class discussion by asking them what they know about clouds based on their observations. The teacher facilitates this discussion with students about what they may already know about various common cloud descriptive characteristics and records their responses under the "K" in a KLEW chart displayed in the classroom.

Explore (day 1, 30 minutes)

The teacher instructs students working in pairs to go outside to use a semi-dichotomous key as a guide to identify clouds (Figure 4). Students should also record the current temperature, atmospheric pressure, wind direction, and precipitation. These data can be obtained by students from the National Weather Service website (*www.weather.gov*) or provided by the teacher if computer access is limited. Students make observations of the sky and any clouds that are present, collect and record data using the semi-dichotomous key, generate conclusions supported with evidence, and further document questions they may have about their observations in a science notebook. Note that teachers should visit any viewing areas prior to taking students to the area and comply with school and district guidelines for taking students outside the school building.

Explain (day 2, 20 minutes)

The teacher asks a few individual students to share with the rest of the class what they have learned about common cloud descriptive characteristics based on the evidence/data they collected using the semi-dichotomous key. The teacher records students' responses under the "L" and "E" in the KLEW chart displayed in the classroom. As students articulate their explanations supported with evidence/data, the teacher introduces new vocabulary terms (i.e., *precipitation*, *elevation*,

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| FIGURE 4 | Semi-dichotomous cloud key |

A version of the cloud key containing color photos of each cloud type can be found at *http://wvscience.org/clouds/Cloud_Key.pdf.*

1. Is it raining?

No: Go to number 2.

Yes, with thunder, lightning, or heavy rain: Your cloud is a cumulonimbus.

Yes, with drizzly, small raindrops: Your cloud is a nimbostratus.

2. Is it a high, wispy cloud, like a horse's tail?

No: Go to number 3.

Yes: Your cloud is a cirrus.

3. Is it flat and layered, puffy and bumpy, or some of both?

Flat and layered cloud: Go to number 4.

Puffy and bumpy cloud: Go to number 5.

Some of both: If your cloud is nearly a solid layer of large puffs (greater than the size of your fist), your cloud is a stratocumulus.

4. Determine how high and thick your flat, layered cloud is.

If your cloud is high and thin, and the Sun is shining brightly and casting distinct shadows, your cloud is a cirrostratus.

If your cloud is thicker, the Sun is dimmer, and there are hardly any shadows, your cloud is an altostratus.

If your cloud is a low cloud, so low it's hard to see the bottom, and it covers most of the sky, your cloud is a stratus.

5. Hold your hand up toward your cloud. Look at the size of the puffs, and compare them to your hand.

If the puffs are the size of your fingernail (very small), your cloud is a cirrocumulus.

If the puffs are the size of your thumb (medium size), your cloud is an altocumulus.

If the puffs are the size of your fist (large), your cloud is a cumulus.

FIGURE 5	Typical atmospheric conditions for the midlatitudes of the United States observed with common cloud types

These scenarios can be used during the Evaluate phase for students to predict the cloud types. Other conditions can be omitted to further extend students' thinking.

	Temperature	Atmospheric pressure	Precipitation	Wind direction	Cloud types
Scenario 1	5°C and falling	1,024 millibars and falling	0	From the northwest	Cirrus
Scenario 2	25°C and increasing	1,003 millibars and increasing	3 cm and heavy downpour	From the southwest	Cumulonimbus
Scenario 3	12°C and falling	1,010 millibars and falling	0	From the north	Stratus
Scenario 4	18°C and decreasing	999 millibars and increasing	1 cm and light	From the northwest	Nimbostratus

altitude, *cirrus*, *stratus*, *cumulus*) to explain a lot of what students are describing. Facilitating student use of scientific vocabulary can be accomplished through the use of challenge questions. For example, after a student responds to a question without using vocabulary, the teacher can ask, "How might you use the words *precipitation* and *altitude* in your response?"

The teacher further explains that observing a specific transitional sequence of cloud types over a six-hour time span can be used to predict future weather events. The teacher facilitates a whole-class discussion centered on students' prior experience with changing atmospheric conditions (atmospheric pressure, temperature, wind direction, and precipitation) over time. For example, guided questions are posed about student observations of atmospheric conditions prior to, during, and after passing fronts where the most observable change is an increase or decrease in temperature. Together, the teacher and students co-construct the following patterns: (1) When a warm front passes, you might observe weather conditions such as increasing clouds (in order of expected observed cloud-type sequence: cirrostratus, altostratus, nimbostratus), light and steady precipitation, falling atmospheric pressure until the front passes, warming temperatures, and winds from the south, and (2) when a cold front passes, you might observe weather condi-

tions such as increasing clouds (in order of expected observed cloud-type sequence: cirrocumulus, altocumulus, cumulonimbus), quick and heavy precipitation, falling atmospheric pressure until the front passes, colder temperatures, and winds from the north.

Elaborate (day 2, 25 minutes; day 3, 45 minutes)

On day 2, one teacher or a group of teachers maintains a data set across classes. Students from each class go outside to record the cloud type using the key, atmospheric pressure, temperature, wind direction, and precipitation as they did in the Explore phase. Students are instructed to work in pairs to collect and record data using the semi-dichotomous key and document their observations to the common data set maintained by the teacher(s). Each class throughout the day then adds data to a common data set for all classes taught by the teacher(s) to utilize. After all the data are collected, each class will have access to the data for analysis of the observed sequence of cloud types the following day.

On day 3, the teacher instructs students to examine the common data set from day 2 and indicate whether they believe a warm front or cold front passed by the school on the previous day. In their small groups, students are asked to cite specific evidence from the

data set to justify their predictions. The teacher facilitates the discussion to encourage students to consider alternative conclusions and discuss the merit of each conclusion while demonstrating the importance of the crosscutting concept of patterns (scientists utilize the presence of patterns to facilitate predictions). Students are then instructed to describe the type of weather event that occurred the previous school day based on the observed sequence of cloud types and trends in the other atmospheric conditions from the common data set. The teacher facilitates a whole-class discussion and allows students to articulate their responses. Students then reflect on what they learned and develop questions they have about clouds and weather in their science notebook. After a few minutes, the teacher allows student to share their wonderings and records their responses under the "W" in the KLEW chart in the classroom. For homework, students can be asked to investigate their wonderings using the internet, collect and document data, and generate conclusions to their particular wondering supported with evidence in a science notebook. The next day, a few students share with their classmates what they have learned and their findings, and the assignment is collected.

Evaluate (day 4, 45 minutes)

As a culminating evaluation activity, the teacher presents each student with one of four weather-prediction scenarios (temperature, wind direction, atmospheric pressure, or precipitation) for the classroom's hometown and climate region. For instance, the teacher might tell a student that the temperature is 5°C and falling, the wind direction is northwest, the atmospheric pressure is 1,024 millibars and falling, and the precipitation is 0 (Figure 5 contains this scenario along with other examples). Students then use this information to draw the associated cloud type in the expected position on a worksheet that contains the sky map employed earlier in the lesson. After making their predictions, individual students are called upon to describe the evidence used to justify those predictions. Other students who were assigned the same scenario are then asked to describe the extent to which they agree with the cloud type and position proposed by the original student. Thus the assessment for this activity is based on students' ability to draw the correct cloud type for the weather forecast and place it in the correct position on the sky map. For our example prediction scenario, students should have drawn a cirrus cloud.

Conclusion

The inquiry-based approach presented above is in line with the National Science Education Standards' recommendation of encouraging students to carefully observe what they see, notice patterns and changes over time, note their properties, and distinguish one from another (NRC 1996). Possessing an understanding of clouds and transitional sequences in cloud types is an essential component of predicting future weather events. Students typically enjoy this lesson and often state they have developed a newfound appreciation for clouds, as they now have a clearer understanding of the role they play in indicating present and future weather events. Moreover, students are excited to share this information with their families and often tell stories of instances where they were successful in predicting weather changes during time spent outside of school. ■

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